CALIFORNIA DIVISION OF MINES AND GEOLOGY

FAULT EVALUATION REPORT FER-125

November 24, 1981

1. Name and location of fault.

Maacama fault, Brooktrails Ranch to Spy Rock Road area, northern Mendocino County, California (see Figure 1).

2. Reason for evaluation.

Part of a state-wide program to evaluate and zone active faults in California (see Hart, 1980).

3. References.

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Hart, E. W., 1980, Fault-rupture hazard zones in California: California Division of Mines and Geology Special Publication 42.

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U. S. Army Corps of Engineers, San Francisco District, 1978, Maacama fault study, Sonoma and Mendocino Counties, California.

U. S. Department of Agriculture, 1952, Black and white aerial photographs, scale approximately 1:20,000, flight CVN.

Upp, R. R., 1981. Map of the Maacama fault zone (preliminary) with Appendix A, in Holocene activity on the Maacama fault: Stanford University, Ph.D. thesis work in progress (map filed with CDMG, San Francisco District Office).

4. Summary of available data.

The Maacama fault zone consists of a series of right-lateral faults along which movement has occurred during Holocene time (Harding-Lawson and Associates, 1977a; Pampeyan, et al., 1981; Upp, 1981). Herd (1978) has suggested that the Maacama fault zone is part of a larger system of faults, the Hayward-Lake Mountain fault system, which bounds the Humboldt and North American plates. According to Herd, the Maacama is connected to the San Andreas fault system via the Rodgers Creek-Healdsburg, Hayward, and Calaveras faults to the south.

Gealey (1951) named the Maacama fault zone and cited evidence of recent movement near Healdsburg, about 50 miles south of the area studied herein. Almost none of the geology of Mendocino County has been mapped in detail. Neither the most detailed geologic map of the area (Jennings and Strand, 1960), nor the Fault Map of California (Jennings, 1975) show any of the faults evaluated herein.

In January 1978, the U. S. Army Corps of Engineers released a study of the Maacama fault. Within the Corps' report were three other reports (Dames and Moore, 1977; Harding-Lawson Associates, 1977a and 1977b). To delineate the Maacama fault (which they called the Talmage fault), Harding-Lawson Associates primarily relied upon aerial photo interpretation, literature research, and limited field reconnaissance. The primary objective of the Corps' study, and the Harding-Lawson study, was to determine the overall length of the active Maacama fault so that the maximum credible earthquake could be estimated.

Harding-Lawson's (197~~8~~7b) 1:24,000-scale maps of the Maacama fault zone cover only the area south of 30° 30' N. In the Willits NW quadrangle, their obviously highly generalized fault map shows from one to three faults in a 2000-foot wide zone (see Figure 2A). There are no annotations on their map of this quadrangle documenting the basis for the location or recency of the faults depicted.

The Corps of Engineers (1978) report also includes 1:62,500-scale maps of the fault. The Corps show the Maacama fault as a zone of discontinuous faults (see Figures 2A to 2E). This zone is depicted as up to two miles wide, in places, extending from near Spy Rock Road southward beyond the area studied herein. The faults that the Corps depict are mostly annotated, although a few are not. Some landslides are also shown. Finally, the Corps (p. 16) concluded that all the features they observed reflected Pleistocene or younger faulting.

After the Harding-Lawson Associates and Dames and Moore studies were completed, a M 4.8 earthquake occurred near Willits. During the post-earthquake investigation, Harsh detected evidence of fault creep in downtown Willits about two miles southeast of Brooktrails Ranch (Simon, et al., 1978). Subsequently, quite convincing evidence of fault creep has been documented near Ukiah, about 20 miles south of the study area, as well as in Willits (Harsh, et al., 1978: Pampeyan, et al., 1980 and 1981; Upp, 1981; Smith, 1981).

Pampeyan, et al. (1980 and 1981, the two of which are identical) delineated the Maacama fault zone in and southeast of the area evaluated herein. They show "lineaments and features interpreted to be the result of recent (Holocene) movements with the Maacama fault zone." Their map is annotated, but they state (p.5) that only "especially clear" features are noted.

The zone of faulting depicted by Pampeyan, et al., which ranges from about one-half to five miles wide in the area studied, consists of a series of discontinuous, subparallel faults (see Figures 2A, 2B, 2C, 2D, and 2E). Several of these faults are not annotated. It is not always clear from the map which faults they consider to be the main active break. They state (p. 6) that evidence of recent fault movement is well-developed about four miles south of Laytonville, where several offset drainages, sag ponds, and trenches are visible over a distance of three miles (see

Figures 2C and 2D). They further state that along Long Valley Creek, to the south, extensions of these lineaments are "poorly defined or unrecognizable." They indicate that some less prominent lineaments mapped by the Corps of Engineers (1978) on the east side of Laytonville Valley are not shown on their map.

Pampeyan, et al., state they interpreted black and white aerial photographs of the area studied herein. They also state that only a few of the lineaments northwest of Willits were field checked. According to a small index map, they only interpreted 1:80,000-scale photos for most of the area studied here; 1:24,000- and 1:35,000-scale photos were used only in the southeasternmost and northernmost parts of the study area.

Upp (1981) has also prepared a map of the Maacama fault zone (Figures 2A, 2B, 2C, 2D, and 2E). He not only identified many geomorphic features present along the various faults, but also attempted to indicate how certain he was that Holocene movement had occurred along each segment. The overall width of the zone of faults he shows ranges from about one to three and one-half miles; however, all of the faults he believes are probably (greater than 50 percent certainty) or certainly (greater than 85 percent certainty) Holocene lie in a fairly narrow zone less than one-half mile wide. He shows all other faults as possibl~~e~~y Holocene (20 to 50 percent certainty).

Upp indicates in his Appendix A that there are several fault traces along which Holocene movement has probably (greater than 50 percent certainty) occurred in the area between Brooktrails Ranch and Rowes Creek (Figure 2A). Between Rowes Creek and Dutch Henry Creek (Figure 2C*),

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*Note: There are two Dutch Henry Creeks in the study area, one on Figure 2C and one on Figure 2A.

he reports that the recently active trace of the Maacama fault is largely obscured by numerous landslides and Franciscan melange. Near Dutch Henry Creek (Figure 2C), Upp (p. 19) cites the existence of several short, "somewhat disorganized" faults that are probably Holocene in age (greater than 50 percent certainty). Slightly to the north, Upp indentifies the southern end of his "Laytonville Fault segment," noting that Wilson Gulch and other drainages are right-laterally deflected. Upp indicates this segment has almost certainly been active during the Holocene, as evidenced by sag ponds, deflected drainages, and similar features. He also reports this fault appears to "die out" to the north; the faults he depicts to the north (Figures 2D and 2E) may have been active during the Holocene, but such activity is "questionable" (Upp, 1981, Appendix A).

The faults mapped by Upp (1981) are quite similar to those mapped by the Corps of Engineers (1978), although Upp mapped more faults and shows more continuity. Also, Upp annotated his maps more extensively than did the Corps. A comparison of the maps of Upp (1981), the Corps of Engineers (1978), and Pampeyan, et al. (1981) reveals that all generally agree on the locations of recently active faults where their data for recency are best (south of Rowes Creek, Figure 2A; and, between Dutch Henry Creek and Tenmile Creek, Figures 2C and 2E). Where the evidence for recency is not as clear (primarily in landslide areas or intensively sheared melange terrain), Pampeyan, et al., often differs substantially from Upp and the Corps.

5. <u>Air photo interpretation and field observations.</u>

U. S. Department of Agriculture (1952) aerial photographs were interpreted in order to detect evidence of recent faulting. NASA (1972) photos supplemented the U.S.D.A. photos, but were not nearly as useful. All of the faults depicted by Upp (1981), Pampeyan, et al. (1981), and the Army Corps of Engineers (1978) were examined on the photographs, and were selectively annotated (in red on Figures 2A through 2E). In addition, some sites were field checked. Such field observations were very limited because of the paucity of access roads, the rugged terrain, and the limited time available to complete this evaluation. No evidence of fault creep was found in the study area.

Much of the study area is underlain by Franciscan materials, although continental deposits, presumed to be Quaternary in age, are present near Laytonville. The Franciscan in the area includes several types of rock, including sandstone, shale, greenstone, serpentine, and unstable melange. These highly contrasting lithologies, coupled with the landslide-prone melange, frequently result in the development or enhancement of features that are permissive evidence of recent faulting. Several such features have been identified by Upp (1981), Pampeyan, et al. (1981), and the Corps of Engineers (1978), and form the basis for many of the faults each depicts. Such features appear to account for the width of the zone of faulting depicted by Upp and Pampeyan, et al., in particular.

Based on the photos interpreted, it appears that a relatively narrow, reasonably well-defined, zone of recent faulting is present in the area studied. Locally, the recent faults are obscured by landslide deposits or are not well expressed (especially in some melange areas). Also, the recent faulting has been complicated locally by pre-existing geologic structures which strike oblique to the direction of principal stress.

In the Willits NW quadrangle, there appears to be only one clearly identifiable Holocene fault south of Section 26, (T19N, R14W). Several features permissive of recent faulting are present along the trend shown on Figure 3A. The number and variety of these features, as well as the existence of one closed depression, the continuity of the zone, and the presence of more definitive geomorphic evidence to the southeast and north strongly suggest this is the active trace.

Near Twin Rocks (Section 23), the faulting is complicated by landslides and Holocene lateral spreading (Figure 3A). An excellent example of a ridge rent or lateral spread fault (probably caused by lateral spreading) exists in NE¼ Section 15 (T19N, R14W; Figure 3B). The development of this feature during the Holocene is inferred from the presence of a closed depression and sidehill trench. The recent faulting to the west can be traced northward to about the center of Section 4 with reasonable certainty.

Between Section 4 (T19N, R14W) and Section 19 (T20N, R14W) are several large landslides (Figure 3B). In places the approximate location of the fault may be generally inferred, but specific evidence for recent faults is lacking. From about Sam Watt Rock (Section 29) northward to Dutch Henry Creek, all evidence of recent faulting has been obliterated by recent landslide movement.

To the north, in the area of Sections 13 (T20N. R15W) and 18 (T20N, R14W), there are several lines of features apparently produced by recent faulting or fault-like movements. The western margin of this zone is defined by a clearly recognizable line of scarps, right-laterally deflected drainages, a linear trough, and similar features. The eastern margin appears to be the main trace of the active fault since it can be traced northward for several miles. Along this eastern fault, a small shutter ridge, with opposed drainages on either side, was observed in the field. Between the eastern and western faults are several northwest-trending troughs and small valleys, one or two of which appear to contain closed depressions. The width of the zone in this area may be due to pre-existing local geologic structure, lateral spreading, or the fact that the trend of the main fault changes in this area.

Essentially, a single, well-defined line of recent fault-produced features is present from Section 7 (Figure 3B) northward to Section 25 (T21N, R14W; Figure 3C). Indeed, these features are the best evidence for the existence of a Holocene fault in the northern part of the study area. Late Quaternary terrace gravels exposed in the creekbanks (Section 25) crossing this trend appear to have a vertical fabric. Also, in Section 25, the fault is bounded by Pleistocene or Pliocene continental deposits on the east and Franciscan on the west.

North and west of Section 25 (T21N, R15W), Upp (1981), Pampeyan, et al. (1981) and the Army Corps of Engineers (1978) have suggested several possible traces or branches of the Maacama fault. However, conclusive evidence of Holocene movement is lacking along any of the faults they delineate. Although I have identified an additional possible fault trace (Figure 3D), the evidence does not conclusively demonstrate that these features are fault-produced or indicative of recent movement. Additional features permissive of Holocene faulting are present to the north of Laytonville (data not included in this FER).

6. Seismicity.

Dames and Moore (1977) conducted a detailed study of the seismicity along the Maacama fault. They report that relatively complete records and locations of earthquakes are available only for the period since 1962. They state that the apparent lack of recorded earthquakes less than M 3.5 north of Willits (southeast of the study area) is probably related more to the detection capabilities of the University of California and U. S. Geological Survey seismic networks than to the lack of seismicity.

Dames and Moore directed their efforts at detecting microearthquakes along the Maacama fault zone. While the seismographic record from 1906 to 1976 does not clearly show a zone of greater seismic activity along the Maacama, the microseismic survey, conducted over a 72-day period ending September 23, 1977, does appear to document seismic activity associated with the Maacama fault. The zone of activity seems to be centered about five kilometers east of the mapped trace. Dames and Moore reported that the northern end of this zone of microseismicity is located about 10 kilometers north of the northern end of the fault as mapped by the Corps of Engineers (1978). They reported that the fault plane solutions were consistent with right-lateral, strike-slip movement.

A M 4.8 earthquake occurred near Willits in November 1977, just after the Dames and Moore study concluded. Simon, et al. (1978) suggested, based on University of California, Berkeley data, that this epicenter was located about nine miles east of the Maacama fault.

7. Conclusions.

Geomorphic features indicate that Holocene, right-lateral displacement has occurred along a fairly well-defined zone extending from the Willits NW quadrangle to the Laytonville quadrangle (Figures 3A, 3B, and 3C). This zone is an extension of the Maacama fault, along which historic fault creep has been documented in Willits, three kilometers to the southeast of the study area (Smith, 1981). In addition, seismicity in the study area appears to be associated with the Maacama fault. Locally, the fault is not well defined. It is difficult or impossible to detect the fault in some highly unstable areas even though an active fault may be present (for example, between Section 4, T19N, R14W and Dutch Henry Creek, Figure 3B). Evidence suggests that lateral spreading of the ridges may have complicated the picture locally (near Section 15, T19N, R14W, and Section 13, T20N, R15W). Where fault-like features probably produced by lateral spreading (ridge rents) are remote from the zone of recent strike-slip faulting, they have not been zoned. Some probable ridge rents closely associated with recently active traces of the Maacama fault have been zoned, since tectonic movement may occur along part of all of the feature. The likelihood of such an event is probably lower the farther the feature is from the main, active, fault trace.

Although Dames and Moore (1977) have documented a zone of microseismicity having a northern terminus several kilometers north of Laytonville, the zone of Holocene faulting does not appear to be sufficiently well defined through and north of "Laytonville Valley."

It appears that the criteria and methodology used by Upp (1981), Pampeyan, et al. (1981), and the Corps of Engineers (1978) differ substantially from that used for the Alquist-Priolo Project. As a result, the conclusions regarding location and recency of faulting also differ substantially. Except for those faults or fault segments which coincide with those depicted in Figures 4A, 4B, and 4C, the faults and lineaments shown by Upp, Pampeyan, et al., and/or the Army Corps of Engineers do not appear to be sufficiently active and well-defined to warrant zoning.

8. Recommendations.

Those faults delineated on Figures 4A, 4B, and 4C should be zoned. Because the meaning of the line symbols used by Upp (1981) and Pampeyan, et al. (1981) differ from those used on the Special Studies Zones maps, the faults should be depicted and zoned as shown on Figures 4A, 4B, and 4C. The locations of the faults shown were obtained principally from this FER, (Figures 3A, 3B, and 3C) and are partly supported by data of Upp (1981), Pampeyan, et al. (1981), and the Army Corps of Engineers (1978). Therefore, these references should be cited on the SSZ maps.

9. Investigator; date.

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November 24, 1981

I agree with recommendations except that the proposed SSZ in the southern part of the Longdale qd (Fig. 4B) probably should be extended a mile or two to the north.

EWH
7/6/82

Legend for Figures 2A – 2F.

Source of data:


U.S. Army Corps of Engineers: Fault, dashed where inferred.


Pampeyan, et al: solid = obvious evidence of recent fault movement; ~~lo~~ dashed = less obvious evidence, but probably a fault; short dash = inferred to be a recent fault but evidence is inconclusive.

 20-50
 50-85
 >85

Upp: Solid where field checked. Line ~~w~~ weights indicate % certainty of Holocene fault movement (as indicated, 20-50%; 50-85%; and >85%.


Harding-Lawson Associates (Fig. 2A only)

Brief annotations in red by Smith (this FER) along selected faults.

n = notch
tr = trough or trench
dd = right-laterally deflected drainage
ls = linear stream
ld = linear drainage
sp = sag pond
cd = closed depression
sw = swale
b = bench
s = saddle
bis = break in slope
lv = linear valley
tf = triangular facet
lt = linear trough
bhd = beheaded drainage
m = marsh
shb = side-hill bench
sc = scarp
mm = scarp

(A) = from U.S. Army Corps of Engineers
(P) = from Pampeyan, et al
all other symbols from Upp.

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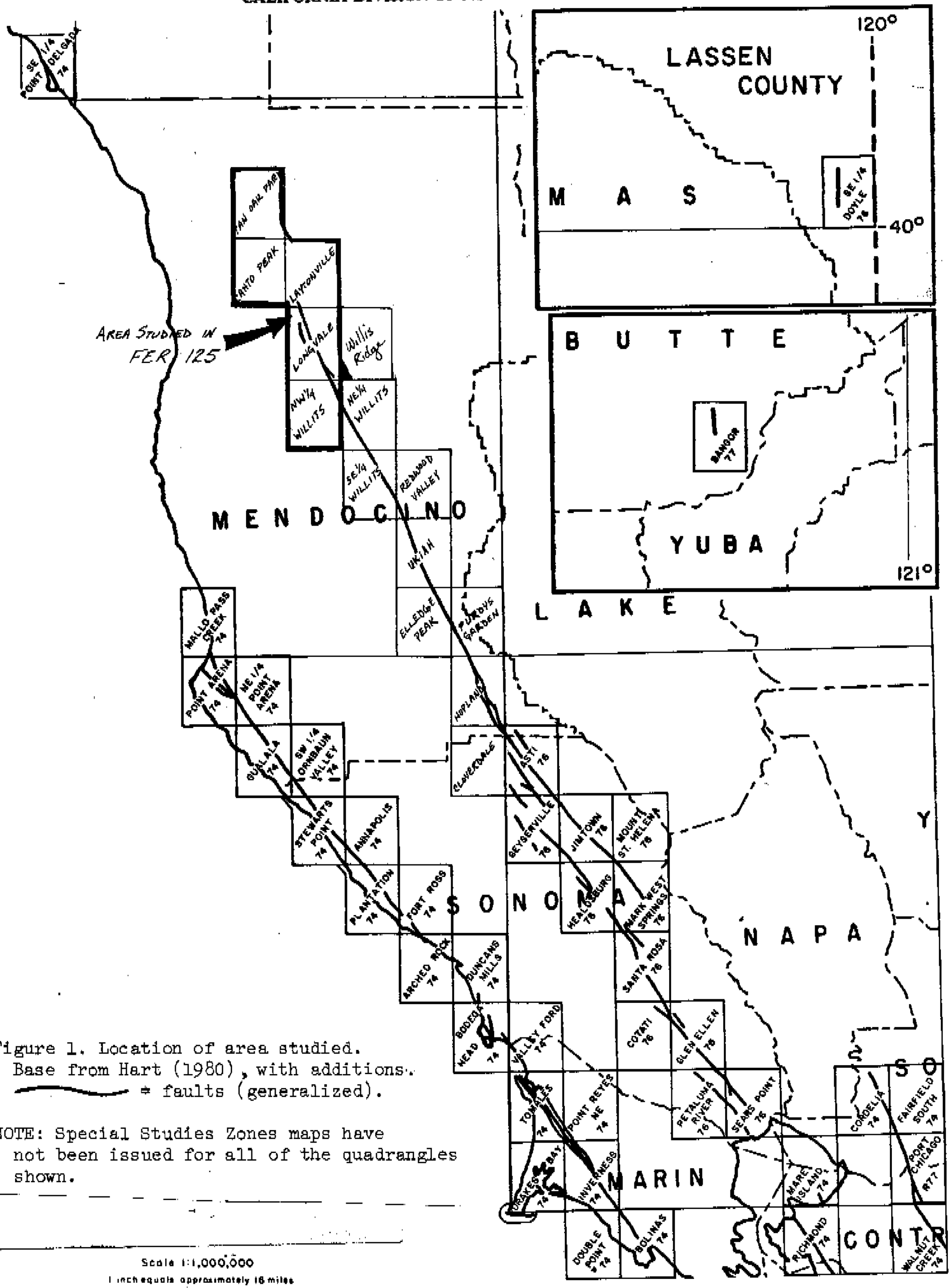
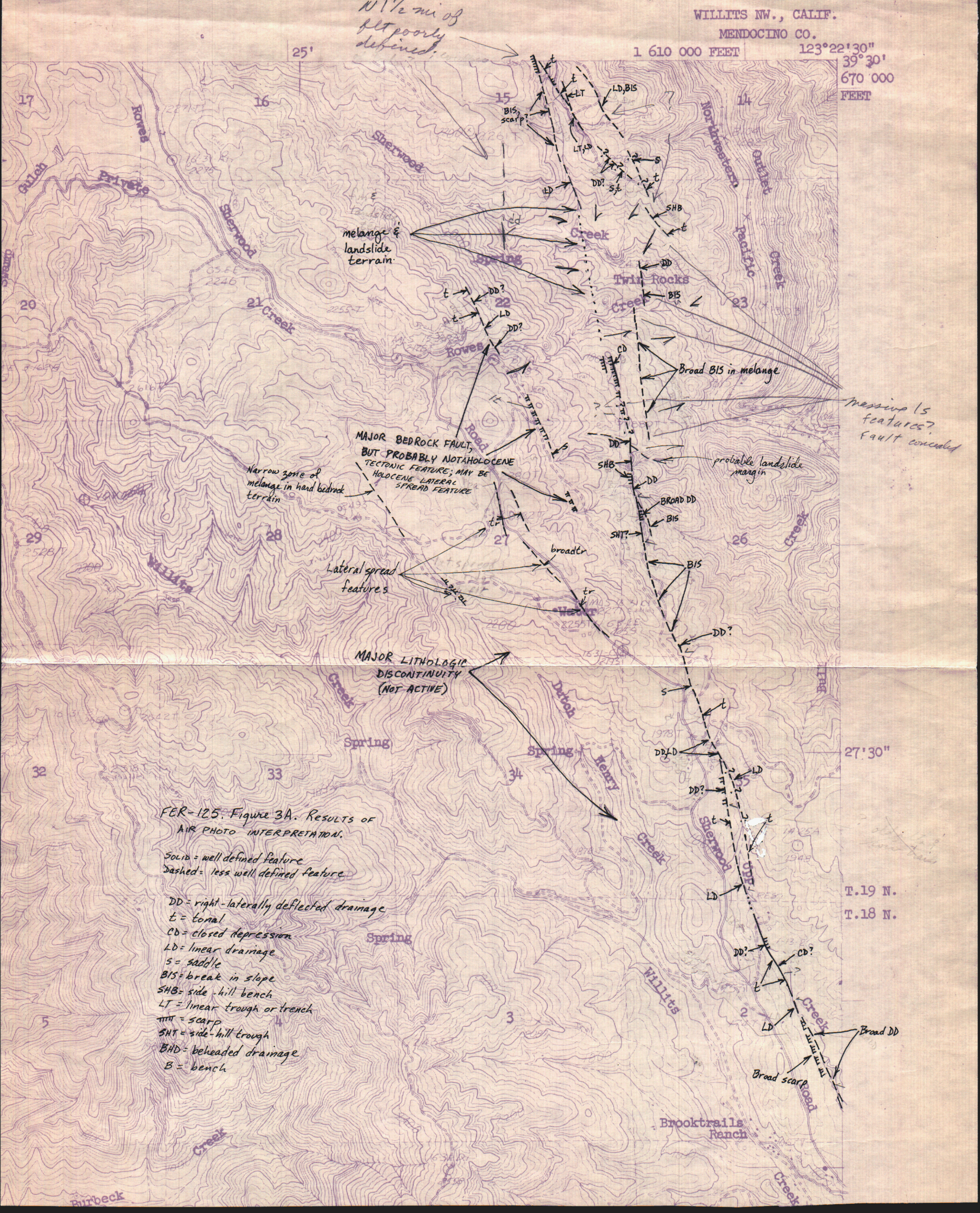


Figure 1. Location of area studied.
Base from Hart (1980), with additions.
——— = faults (generalized).

NOTE: Special Studies Zones maps have not been issued for all of the quadrangles shown.

Scale 1:1,000,000
1 inch equals approximately 16 miles


WILLITS NW., CALIF.
MENDOCINO CO.
123°22'30"
39°30'
670 000
FEET
1 610 000 FEET
25'
27'30"
T.19 N.
T.18 N.
N 1½ mi of flt poorly defined.
melange & landslide terrain
Broad BIS in melange
massive ls features? Fault concealed
probable landslide margin
MAJOR BEDROCK FAULT, BUT PROBABLY NOT HOLOCENE TECTONIC FEATURE; MAY BE HOLOCENE LATERAL SPREAD FEATURE
Narrow zone of melange in hard bedrock terrain
Lateral spread features
broad tr
MAJOR LITHOLOGIC DISCONTINUITY (NOT ACTIVE)
Broad scarp
Broad DD
FER-125. Figure 3A. Results of air photo interpretation.
Solid = well defined feature
Dashed = less well defined feature
DD = right-laterally deflected drainage
t = tonal
CD = closed depression
LD = linear drainage
S = saddle
BIS = break in slope
SHB = side-hill bench
LT = linear trough or trench
scarp
SHT = side-hill trough
BHD = beheaded drainage
B = bench
Sherwood
Creek
Spring
Twin Rocks
Rowes
Road
Northwestern
Pacific
Outlet
Private
Gulch
Willits
Dutch
Henry
Brooktrails
Ranch
Burbeck
Water
Bull

FER 125. Fig. 4A.
RECOMMENDED SPECIAL STUDIES ZONES.